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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : B29C 47/90, 55/24, B29L 23/22 B29K 27/06

A1

(11) International Publication Number: WO 90/02644

(43) International Publication Date: 22 March 1990 (22.03.90)

(21) International Application Number: PCT/AU89/00398

(22) International Filing Date: 15 September 1989 (15.09.89)

(30) Priority data:
PJ 0427 15 September 1988 (15.09.88) AU

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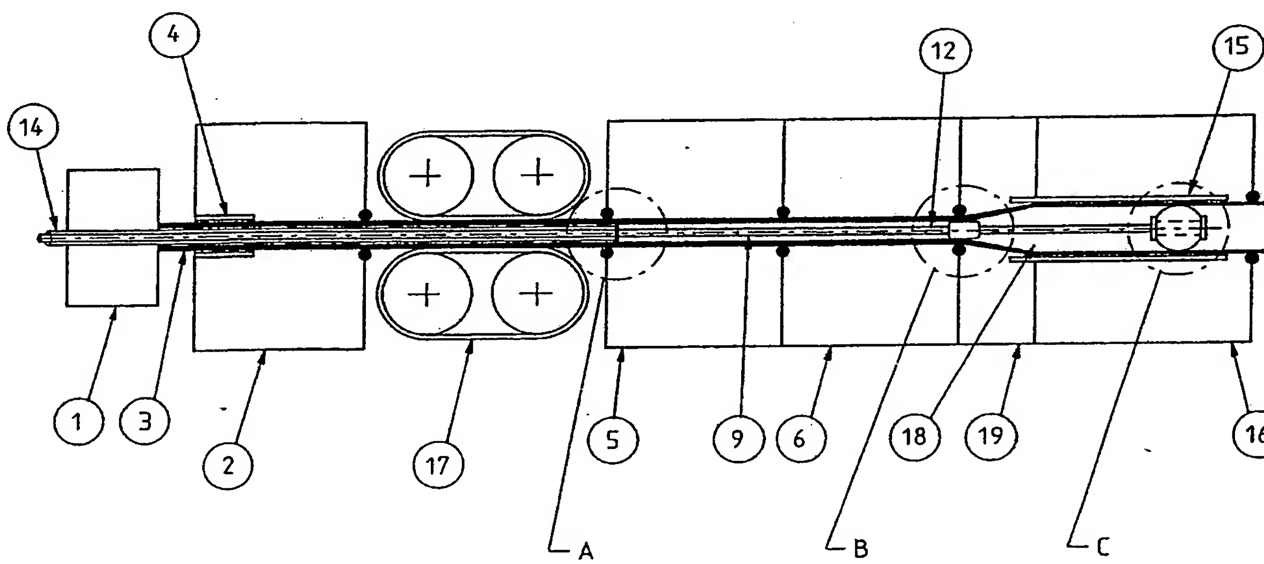
(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.

(54) Title: METHOD OF PIPE MANUFACTURE



(57) Abstract

A method of producing a thermoplastics material pipe having a wall which is drawn or stretched to achieve material orientation. The method includes the steps of continuously effecting an intial extrusion of a tube (3), temperature conditioning to a desired orientation temperature, expanding the tube by pressure within an internal pressure region (18) and cooling. In one form of the invention, the internal pressure region is limited at its downstream end by an expandable plug (8). In another form of the invention, the extruded tube is brought to the desired orientation temperature by cooling the outer surface of the wall to below the desired temperature, subsequently heating the outer surface of the tube wall and then temperature conditioning the tube wall.

METHOD OF PIPE MANUFACTURE

BACKGROUND ART

This invention relates to a process and apparatus which can be used to produce thermo-plastic pipes of enhanced characteristics, and to pipes made by that process. The process has particular application to the enhancement of burst pressure and tensile strength of uPVC pipes.

It is well known that the tensile strength of thermoplastic materials can be enhanced by molecular orientation induced by stretching or drawing the material, usually at an elevated temperature, followed by cooling to lock in the orientation. The basic principles of orientation of pipes and tubes are described in the literature. Diedrich et al (US Patent No. 2961711) descibes the processing conditions appropriate generally to polyolefin materials and the general method for drawing or stretching as a continuous (on-line) or discontinuous (off-line) process. Yazawa et al (US Patent No. 3313870) also teaches a method primarily applicable to thin film tubes.

Both of these methods employ internal hydraulic or pneumatic pressure to effect expansion of an extruded tube. Whilst it is claimed that the processes can be applied to thick-walled pipes, neither patent discloses a practicable mechanism for starting the process in this case, nor a satisfactory method of control over the external diameter of the product, as is required for practical pipe applications.

A further major problem not addressed by these authors relates to attainment of the appropriate thermal conditions for the orientation of thick-walled tubes. We have found that a high degree of temperature uniformity

is required to achieve dimensional stability of wall thickness when expanding tubes, since variations in temperature of the material result in variations in the rheological properties, with varying visco-elastic response to stress around, along and/or through the wall of the tube. This is particularly critical for materials such as polyvinyl chloride (PVC) for which properties change markedly in the vicinity of the optimum temperature for orientation, that is, where the greatest capacity for material strain can be achieved.

For thin-walled tubes such consistency of temperature is comparatively easy to achieve, but for thick-walled tubes the conditioning time required is so long as to render on-line processing impracticable, because of the length of the conditioning bath, unless special procedures are adopted. This factor is one reason that commercial applications to date of orientation of plastics pipe have mostly relied on off- line processing, where the conditioning time may be attained without difficulty.

A procedure for conditioning the tube on-line using multiple conditioning baths heated to different temperatures is suggested by Petzetakis (West German Patent No. 2357210). However no explanation is offered as to the advantage of the multiple baths, and since they are said to be heated, there would appear to be no gain in terms of shortened conditioning time. His method of drawing the tube however relies on stretching over a solid mandrel attached rigidly to the extrusion equipment. Such an apparatus is necessarily limited in length because of the weight of the mandrel and hence the capacity for temperature conditioning of the tube is also limited. No positive control of external diameter of the expanded pipe is provided in this method, and further, it suffers the disadvantage that the pressurised lubricating fluid must be supplied to the surface of the mandrel to

minimise friction between the tube and mandrel, which fluid must escape downstream into the inside of the expanded pipe.

It is the object of this invention to propose means and methods of overcoming these various problems, and provide a practicable process for high speed on-line orientation of plastics pipes.

DISCLOSURE OF INVENTION

According to this a first form of the invention, there is provided a method of producing a thermoplastics material pipe having a wall which is drawn or stretched to achieve material orientation, including the steps of continuously:

effecting an initial extrusion of a tube,

temperature conditioning the tube to a desired orientation temperature,

effecting diametral expansion of the tube by pressure within an internal pressure region which is limited at its downstream end by a downstream internal plug which is capable of diametral expansion to maintain a seal against the inner surface of the wall of the expanded pipe, and

cooling the pipe to set the material and fix the material orientation.

In the context of the present invention, the term "tube" is used to denote the extruded material prior to and during the expansion and the term "pipe" is used to denote the tube after expansion. The method is particularly advantageous when the tube produced by the initial extrusion step is a medium- or thick-walled tube.

Preferably, the expanded pipe is passed through a sizing

device such as a sizing sleeve or convex sizing rollers to limit expansion and control the external diameter of the pipe. The sizing device may also cool the pipe.

The expandable plug is preferably expanded by hydraulic or pneumatic pressure, which may be due to hydraulic or pneumatic fluid introduced to a cavity within the plug. The fluid may then be allowed to enter the internal pressure region through one or more orifices in the plug and may further be allowed to enter temperature conditioning zone within the tube through one or more orifices in an upstream plug which limits the upstream end of the internal pressure region.

In one preferred embodiment of the invention, the expansion of the tube is effected by a pressure differential between the internal pressure zone and an external pressure region in which the pressure is adjustable, thereby allowing better control over the rate of expansion.

According to a second form of the invention, there is provided a method of producing a thermoplastics material pipe having a wall which is drawn or stretched to achieve material orientation, including the steps of continuously:

effecting an initial extrusion of a tube,

cooling the outer surface of the tube wall to below a desired orientation temperature,

subsequently heating the outer surface of the tube,

temperature conditioning the tube wall to the desired orientation temperature,

effecting diametral expansion of the tube by pressure within an internal pressure region, and

cooling the pipe to set the material and fix the material orientation.

Preferably, the cooling step results in a temperature profile across the tube wall such that the temperature of the outer surface of the wall is below the desired orientation temperature and the temperature of the inner surface of the wall is above the desired orientation temperature. The temperature profile may be such that the temperatures across the tube wall after the cooling step would tend to equalise below the desired orientation temperature under adiabatic conditions.

The heating step preferably results in a temperature profile across the tube wall such that both the inner and outer surfaces of the wall are above the desired orientation temperature and at least one point within the tube wall is below the desired orientation temperature. The temperature profile may be such that the temperatures across the tube wall after the heating step tend to equalise at approximately the desired orientation temperature.

BRIEF DESCRIPTION OF DRAWINGS

To assist in a further understanding of the invention, one form will now be described with the assistance of drawings for which:

FIG 1 is in the most schematic way an illustration of an apparatus shown in elevation, to effect manufacture in accordance with the invention, but is not intended to disclose in great detail the technical workings of the invention except in general principle;

FIG 2 shows detail A of FIG 1;

FIG 3 shows detail B of FIG 1;

FIG 4 shows detail C of FIG 1;

FIGS 5(a), 5(b) and 5(c) illustrate the temperature profiles across the tube wall; and

FIG 6 illustrates an alternative means for controlling the external diameter of the pipe.

An extruder of standard commercially available type, preferably fitted with an offset or cross head 1, extrudes a thick-walled "feedstock" tube 3 via a standand circular pipe die with a hollow center pin. The tube 3 passes into a cooling bath 2, containing circulating fluid which is held at a temperature well below the desired orientation temperature. At the entrance to bath 2 is a standard sizing sleeve 4 to which the feedstock tube 3 is held by maintaining vacuum in the cooling bath 2, or by applying air pressure internally via the hollow extruder head and die pin. The tube 3 then passes from the cooling bath through a tractor 17, which pulls it from the bath 2 and the extrusion die, moving at regulated speed to control the wall thickness of the tube.

The tube 3 then passes into a heating bath 5, in which the circulating fluid temperature is maintained above the orientation temperature, then enters the finishing bath 6, in which the circulating fluid temperature is maintained substantially at the desired orientation temperature. It continues to move through the finishing bath 6 until the temperature profile across the wall of the tube has evened out to within the desired tolerances of the orientation temperature. In an unillustrated embodiment, the tube may be passed through additional baths at temperatures below and above the orientation temperature.

Internal plug 7 has a fixed external diameter substantially equal to the internal diameter of the feedstock tube. A second plug 8 is fitted at an appropriate point further downstream, to provide a pressurised expansion chamber 18 in conjunction with plug 7. Plugs 7 and 8 are shown in more detail in Figs. 3 and 4 respectively.

Expanding plug 8 effectively enables the process to be started. Plug 8 is capable of diametral expansion, being constructed, in this example, partly or wholly of elastomeric material, and is expanded under applied internal pressure to contact and seal against the internal surface of the wall of the pipe. It has an initial and minimum diameter approximately equal to the internal diameter of the feedstock, and a maximum expanded diameter equal to the internal diameter of the expanded pipe. One form of construction is of low friction elastomeric material, supported by end plates.

Plugs 7 and 8 are affixed to and restrained in position by metal conduit 9, which passes along the full length of the feedstock tube and through and beyond the extruder head, and through which pressurised fluid at a temperature substantially equal to orientation temperature is introduced to the interior of plug 8. The fluid flows back through control orifices 10 into the expansion chamber 18 to provide internal pressure required to expand the feedstock tube, and thence through control orifices 11 into internal temperature conditioning zone 12. As shown in Fig 2, conduit 14, concentric with conduit 9 allows removal of backflow fluid without backpressure, or with slight backpressure if required to maintain shape support of the feedstock tube. Scavenge seals 13 affixed to conduit 14 seal against the internal surface of the feedstock tube 3 to contain the backflow fluid within conditioning zone 12.

Flow of fluid through the orifices 10 causes a drop in pressure in the backflow fluid, such that the pressure in the expansion chamber 18 is maintained at a level somewhat below that in plug 8, the differential being just sufficient to ensure effective sealing action of plug 8. Flow through orifices 11 again causes a pressure drop, and the differential is sufficient to maintain the pressure in the expansion chamber 18 at the level required to bring about expansion of the tube at the desired rate.

In a further embodiment, the expandable plug may be independently pressurised by a hydraulic tube introduced within the delivery pipe 9. In this case fluid for expansion and temperature control is delivered directly to the expansion chamber 18 via conduit 9.

Alternative constructions for plug 8 are possible, for example with expansion produced by mechanical means.

Throughout the expansion, the tube is immersed in the expansion bath 19, in which fluid is circulated also at orientation temperature. Bath 19 may be a continuation of conditioning bath 6, or separated as shown in the schematic. The latter arrangement enables the expansion bath 19 to be pressurised at some lower pressure than that within the expansion chamber 18, or subjected to vacuum, which pressure or vacuum may be independantly adjusted to improve control over the rate of expansion.

Sizing sleeve 15 contains and limits the expansion of the tube and extends from the expansion bath 19 into the cooling bath 16, in which coolant at ambient temperature is circulated. In preference sleeve 15 is a vacuum sizing sleeve, of the standard design and operation used

in general extrusion practice, whereby cooling water is drawn in over the surface of the pipe to better cool and lubricate its passage through the sleeve. The plug 8 is positioned downstream of the start of the cooling bath a distance sufficient to maintain internal pressure within the pipe until the outer surface of the pipe has cooled and hardenned enough for the pipe to be self supporting. The finished pipe is supported and drawn forward by a tractor (not shown), the speed of which is adjusted to provide tension to the pipe and feedstock tube, and to control the degree of draw or stretch in the axial direction induced during the forming process.

The temperature and flow rate of the incoming fluid via conduit 9 are adjusted to maintain the temperature in the expansion zone, monitored by remote sensors (not shown), sensibly at the desired orientation temperature. Orifices 10 and 11 are set to a size required to produced the required pressure drops at this flow rate. Such temperature, flow rate, pressures and dimensions may readily be predicted using known mathematical modelling techniques, given the thermal and rheological characteristics over the relevant temperature range of the thermoplastic material as established for example from laboratory measurement.

Scavenge seals 13 may be positioned anywhere along the feedstock tube, but preferably at the start of conditioning bath 5.

The temperatures, conditioning fluids, and conditions of operation can vary considerably depending on the material subject to orientation. Where the desired temperatures are outside of the range obtainable by using water as the heat transfer medium, other liquids or solutions such as ethylene glycol in water may be appropriate. For example, the cooling bath 2 can be refrigerated, and in

one embodiment may use liquid nitrogen as a heat sink. The heating bath 5 can be sealed to allow high pressures (necessarily compensated by higher backpressure in the internal conditioning zone 12) and thus elevated temperatures.

Temperature profiles across the wall of the tube are illustrated in Figs 5(a), 5(b) and 5(c). The desired orientation temperature is denoted by reference numeral 20 and the upper and lower tolerances are denoted by numerals 21 and 22 respectively. Fig 5(a) show the profile at the end of bath 2, with heat extracted vigorously from the outer surface of the tube. The high rate of heat transfer causes a substantial temperature gradient across the wall. Fig 5(b) shows the profile at the end of bath 5, following external heating by bath 5 and internal cooling by zone 12. Fig 5(c) shows the profile at the end of finishing bath 6, with the temperature profile being within the required tolerances.

The total heat extracted via bath 2 and zone 12 is in excess of that required to bring the temperature of the tube to the target temperature, and this excess is balanced by the surplus heat supplied via bath 5. The lengths of baths and temperatures required to achieve the desired balance can readily be estimated, given the thermal characteristics of the material, heat transfer fluids, and line speeds.

In a further embodiment illustrated in Fig 6, the sizing sleeve 15 is replaced by a set of sizing rollers 23. As shown in Fig 6, the rollers are concave in shape to match the required pipe external diameter, and overlapping in position to provide adequate and uniform support to the pipe. Advantages of this system are the reduction of friction, which is desirable where it is preferred to minimise the degree of axial draw, and also more rapid

cooling of the finished pipe is possible.

Claims

1. A method of producing a thermoplastics material pipe having a wall which is drawn or stretched to achieve material orientation, including the steps of continuously:

effecting an initial extrusion of a tube,

temperature conditioning the tube to a desired orientation temperature,

effecting diametral expansion of the tube by pressure within an internal pressure region which is limited at its downstream end by a downstream internal plug which is capable of diametral expansion to maintain a seal against the inner surface of the wall of the expanded pipe, and

cooling the pipe to set the material and fix the material orientation.

2. A method according to claim 1 wherein the tube produced by the initial extrusion step is a medium- or thick-walled tube.

3. A method according to claim 1 wherein the expanded pipe is passed through a sizing device to limit expansion and directly control the external diameter of the expanded pipe.

4. A method according to claim 3 wherein the sizing device also effects the cooling of the pipe.

5. A method according to claim 3 wherein the sizing device comprises a sizing sleeve.

6. A method according to claim 3 where the sizing device comprises a set of concave sizing rollers.

7. A method according to claim 1 wherein the expandable plug may be expanded by hydraulic or pneumatic pressure.

8. A method according to claim 7 wherein hydraulic or pneumatic fluid is introduced to an internal cavity in the expandable plug.

9. A method according to claim 8 wherein the hydraulic or pneumatic fluid is allowed to enter the internal pressure region through one or more orifices in the

expandable plug.

10. A method according to claim 9 wherein the internal pressure region is limited at its upstream end by an upstream internal plug.

11. A method according to claim 10 wherein the hydraulic or pneumatic fluid passes through one or more orifices in the upstream plug into a temperature conditioning zone within the tube.

12. A method according to claim 1 wherein the diametral expansion of the tube is effected by a pressure differential between the internal pressure region and an external pressure region, the pressure in the external pressure region being adjustable.

13. A method of producing a thermoplastics material pipe having a wall which is drawn or stretched to achieve material orientation, including the steps of continuously:

effecting an initial extrusion of a tube,

cooling the outer surface of the tube wall to below a desired orientation temperature,

subsequently heating the outer surface of the tube wall,

temperature conditioning the tube wall to the desired orientation temperature,

effecting diametral expansion of the tube by pressure within an internal pressure region, and

cooling the pipe to set the material and fix the material orientation.

14. A method according to claim 13 wherein the cooling step results in a temperature profile across the tube wall such that the temperature of the outer surface of the wall is below the desired orientation temperature and the temperature of the inner surface of the wall is above the desired orientation temperature.

15. A method according to claim 14 wherein the heating step results in a temperature profile across the tube wall such that both the inner and outer surfaces of the

wall are above the desired orientation temperature and at least one point within the tube wall is below the desired orientation temperature.

16. A method according to claim 14 wherein the temperatures across the tube wall after the cooling step would tend to equalise below the desired orientation temperature under adiabatic conditions.

17. A method according to claim 15 wherein the temperatures across the tube wall after the heating step tend to equalise at approximately the desired orientation temperature.

18. A thermoplastics material pipe produced by the method of claim 1.

19. A thermoplastics material pipe produced by the method of claim 13.

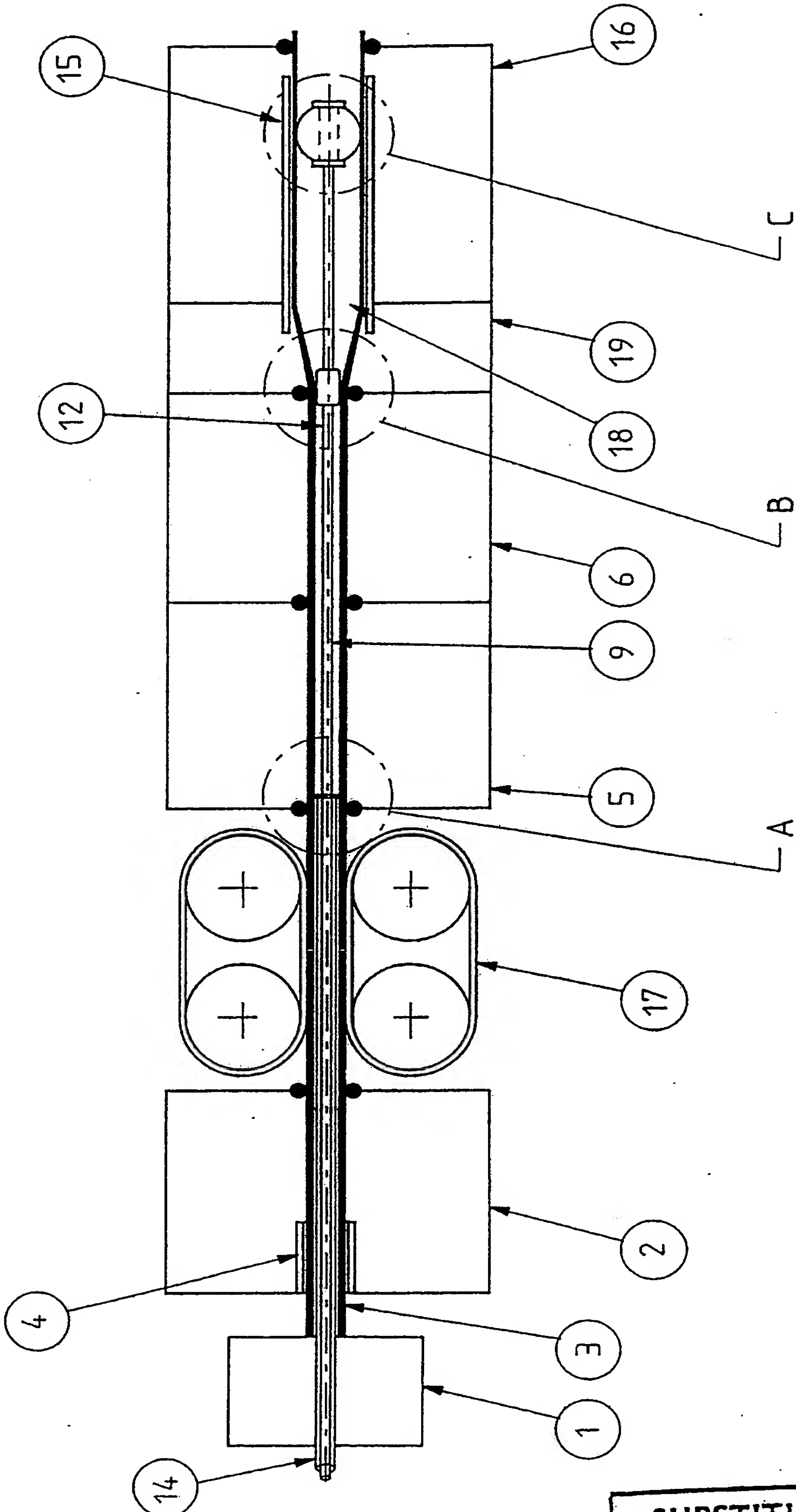


FIG 1

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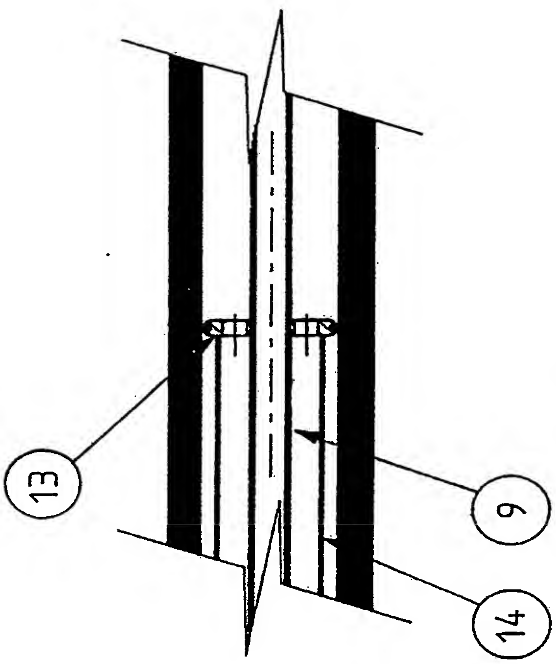

FIG. 2

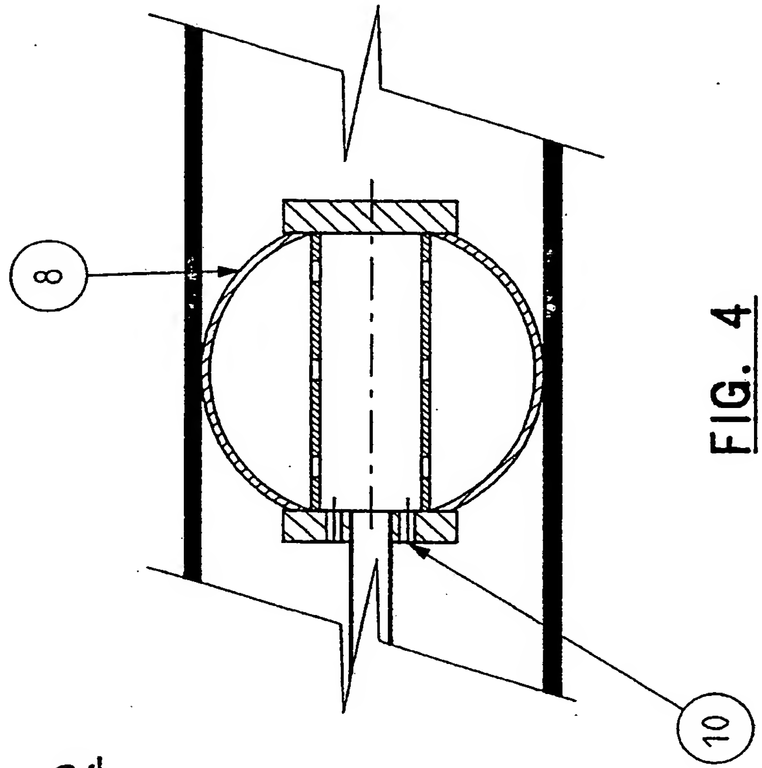

FIG. 4

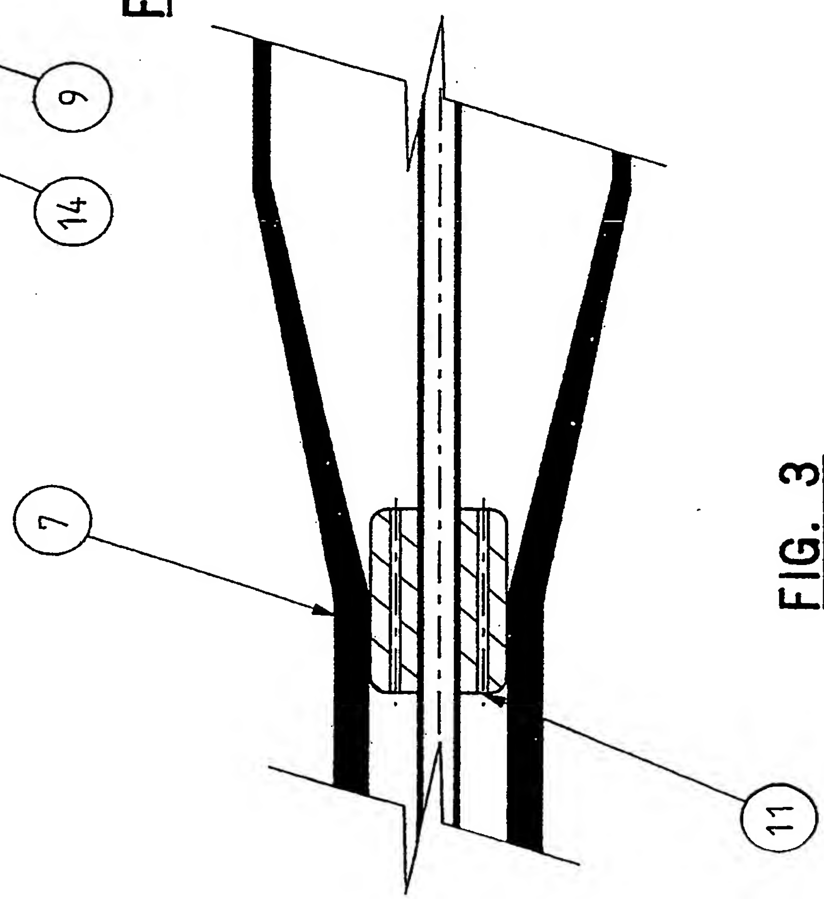

FIG. 3

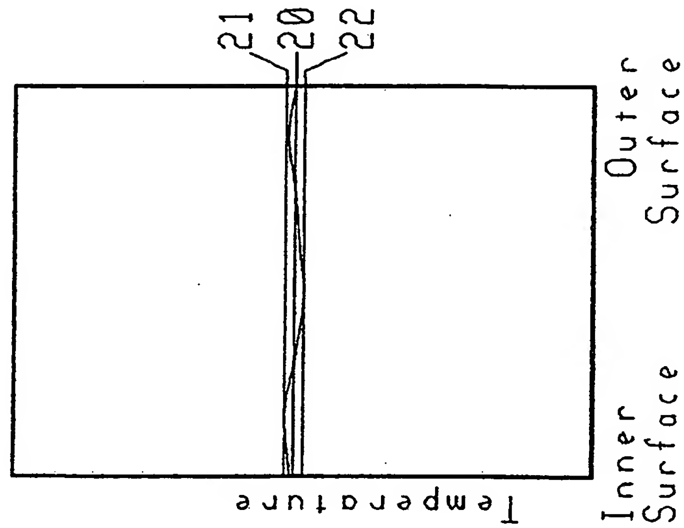

FIG 5(c)

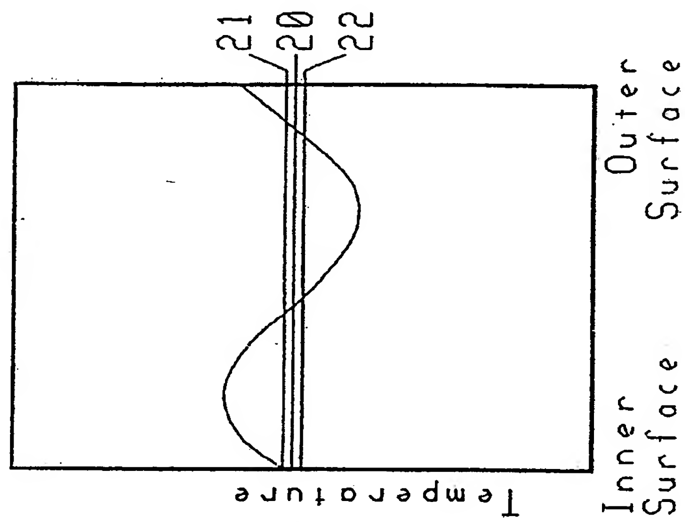

FIG 5(b)

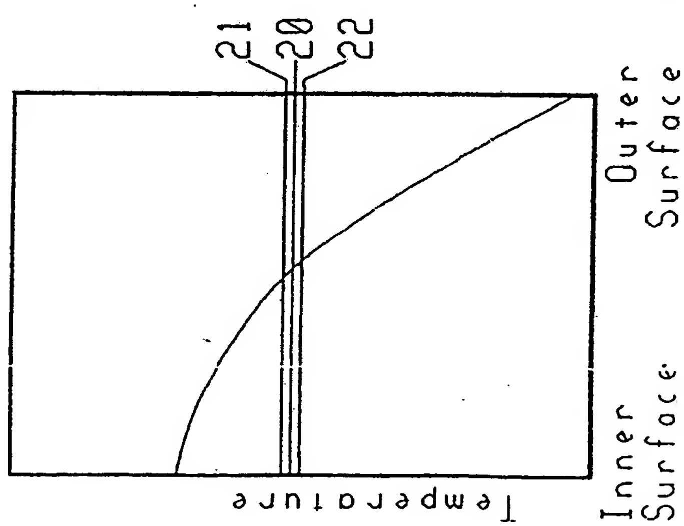

FIG 5(a)

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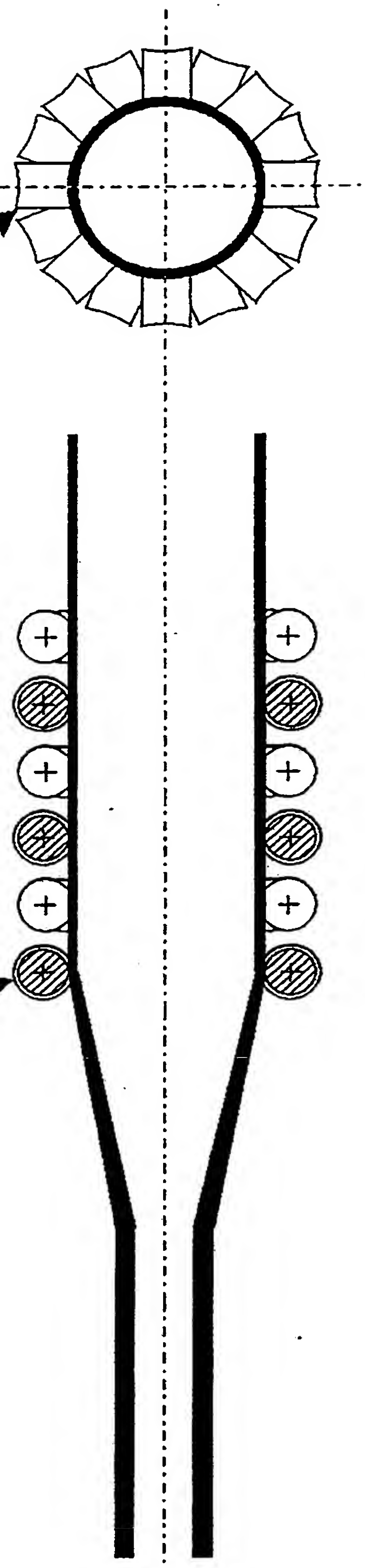

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FIG 6

SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 89/00398

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.⁴ B29C 47/90, 55/24, B29L 23/22, B29K 27/06

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	B29D 23/04, 23/22, B29C 47/90, 55/24, B29F 3/08

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X, Y	US, A, 2961711 (D'EDRICH et al) 29 November 1960 (29.09.60) (SEE WHOLE DOCUMENT)	(1-19)
X, Y	DE, A, 1166458 (KRAUSS-MAFFEI AG) 26 MARCH 1964 (26.03.64) (SEE WHOLE DOCUMENT)	(1-19)

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
11 DECEMBER 1989 (11.12.89)	18/12/89
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	S. Ghosh S. GHOSH

Form PCT/ISA/210 (second sheet) (January 1985)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. [] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.[] Claim numbers, because they relate to subject matter not required to be searched by this Authority, namely:

2.[] Claim numbers, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.[] Claim numbers, because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [X] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

Claim 1 includes the feature of an internal plug whereas claim 13 is silent about it. Also in claim 13 the extruded tube is cooled and then heated before temperature conditioning whereas claim 1 is silent about cooling and heating before temperature conditioning.

1.[]As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. [] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.[]No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. [X] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[] The additional search fees were accompanied by applicant's protest.

[] No protest accompanied the payment of additional search fees.